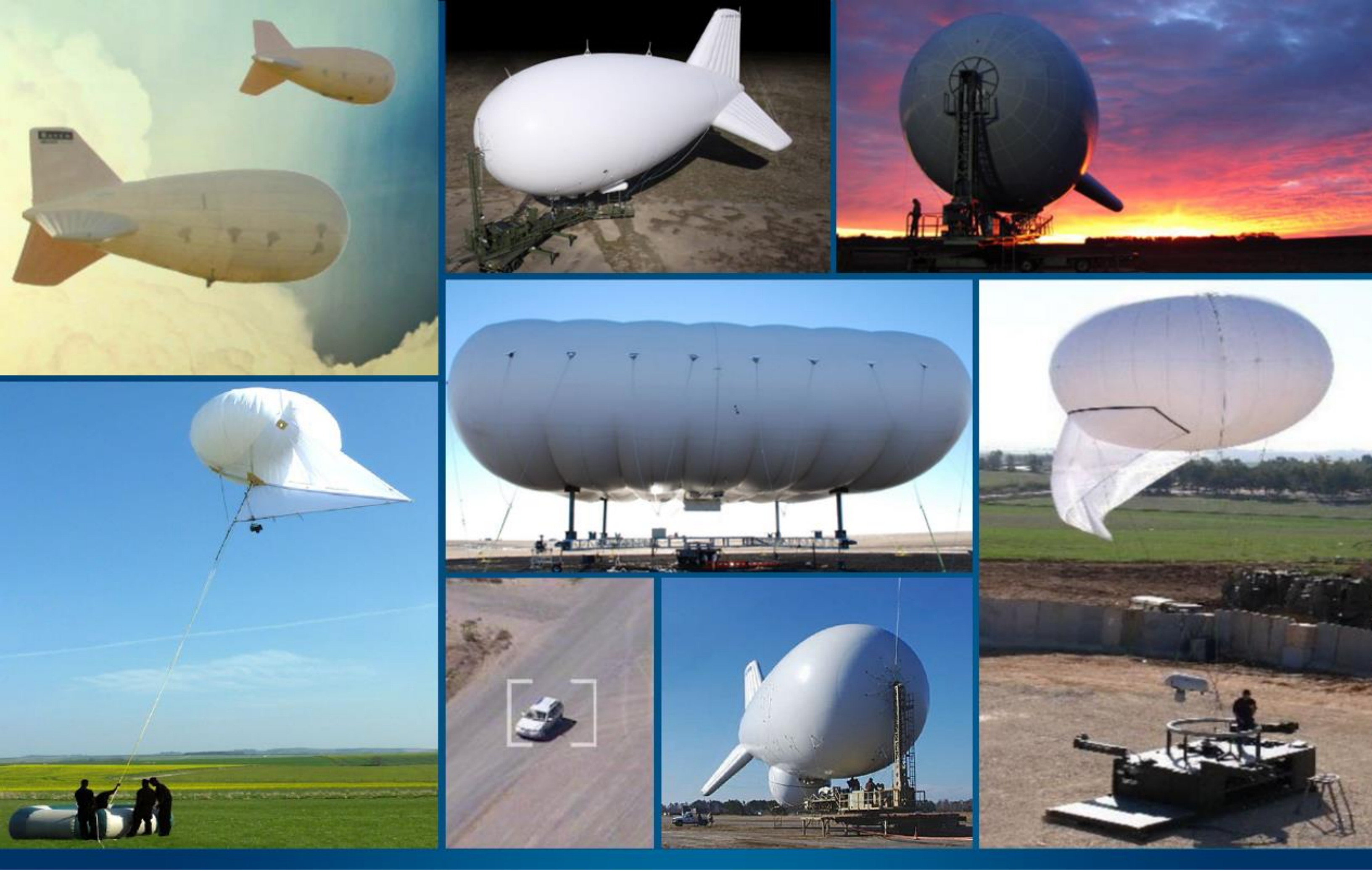

System Assessment and Validation for Emergency Responders (SAVER)

Tethered Aerostat Systems Application Note

September 2013

Homeland Security
Science and Technology

U.S. Department of Homeland Security
SAVER
System Assessment and Validation for Emergency Responders

Prepared by Space and Naval Warfare Systems Center Atlantic

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The cover image is courtesy of Aeros Aeronautical Systems Corporation; Allsopp Helikites Limited; Carolina Unmanned Vehicles; Focus Consulting & Services, LLC; Near Space Systems; Raven Aerostar; and TCOM, L.P. Photos used within the document are courtesy of Allsopp Helikites Limited; Focus Consulting & Services, LLC; Near Space Systems; Raven Aerostar; SkyDoc™ Aerostat; SkySentry; and TCOM, L.P.

FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercial equipment and systems and provides those results along with other relevant equipment information to the emergency response community in an operationally useful form. SAVER provides information on equipment that falls within the categories listed in the DHS Authorized Equipment List (AEL). The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency responder equipment; and
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency responder equipment.

Information provided by the SAVER Program will be shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. Further, SAVER focuses primarily on two main questions for the emergency responder community: "What equipment is available?" and "How does it perform?"

As a SAVER Program Technical Agent, the Space and Naval Warfare Systems Center (SPAWARSYSCEN) Atlantic has been tasked to provide expertise and analysis on key subject areas, including communications, sensors, security, weapon detection, and surveillance, among others. In support of this tasking, SPAWARSYSCEN Atlantic developed the *Tethered Aerostat Systems Application Note* to provide emergency responders with information on tethered aerostat system technologies and their operational uses. Tethered aerostat systems fall under AEL reference number 03OE-07-RPVS Unmanned Aerial Vehicles.

Visit the SAVER section of the Responder Knowledge Base (RKB) website at https://www.rkb.us/saver for more information on the SAVER Program or to view additional reports on aerostat systems or other technologies.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Tethered aerostats are balloons, similar to blimps, which use lighter-than-air gases to take flight and remain aloft while moored by ground equipment. These balloons can carry equipment such as digital cameras or communication repeaters. The integration of a tethered aerostat with information system components can provide emergency responders with a cost-effective means to conduct a variety of tasks including border surveillance, crowd management, and disaster relief.

This application note is intended to present information on tethered aerostat systems and their operational uses and assist emergency response agency decision-makers seeking to implement this technology. This application note is based on information gathered from January to June 2013 from various Internet searches, industry publications, and a government-issued Request for Information (RFI) accessible from the Federal Business Opportunities website.

2. TETHERED AEROSTAT SYSTEM OVERVIEW

A tethered aerostat system requires a number of components to be fully operational. The key component is a balloon filled with lighter-than-air gas that enables the system to take flight and remain aloft. These balloons, usually referred to as envelopes, come in different shapes, sizes, and designs. Normally, helium is used for the lift gas. The other components typically used in a tethered aerostat system include the following:

- A means for transporting the system, such as a truck and/or trailer;
- A mooring station for controlling the inflated aerostat envelope prior to launch;
- A launching platform, which sometimes doubles as the mooring station;
- Tethers used for both mooring the aerostat envelope to ground equipment and for transmitting power and data;
- Winches for letting out, pulling in, and adjusting the tension of the tethers; and
- Automatic or manual deflation devices.

Depending on the needs of the agency, tethered aerostats can support a variety of surveillance and tactical equipment such as high-resolution video cameras, electro-optical/infrared (EO/IR) sensors, communication repeaters, acoustic detectors, and radar. Some tethered aerostat products may also include a ground control station for media storage, data transmission, and system management functions. Ground control stations may also support common operating picture (COP) software, and transportable command and control systems.

2.1.1 Aerostat Envelopes

Aerostat envelopes come in different shapes, sizes, and designs. Some examples of aerostat envelopes are shown in Figure 2-1.

Figure 2-1. Aerostat Envelopes

The shape of the envelope is designed to provide lift while keeping the wind resistance as low as possible. Oblong and spheroid are the most common envelope shapes, and most have either fixed-wing or airfoil attachments to increase stability and provide lift. Envelope dimensions are expressed in terms of length and width; length and diameter; or length, width, and height. The overall space within the envelope, which is its volume, is expressed as a cubic unit of measurement (e.g., cubic feet). Most manufacturers of aerostat envelopes offer standard model sizes, and some will provide customized solutions to meet the specific needs of individual customers.

An example of a small standard envelope measures approximately 5 feet in length and 4 feet in width with a volume of 35 cubic feet. An example of a large standard envelope measures approximately 208 feet in length and 69 feet in width with a volume of 420,000 cubic feet. For these examples, the small envelope can carry equipment weighing half a pound to an altitude of 1,000 feet, while the large envelope can carry equipment weighing 2,000 pounds to an altitude of 15,000 feet.

Aerostat envelopes are typically made from one- or two-ply synthetic fabrics such as polyester, polyvinyl, or polyurethane. Some envelope manufacturers offer customized fabrics, which may include laminates to protect the envelope from degrading due to exposure to ultraviolet light and lightweight casings to protect the envelope from abrasions. The envelope may also contain a structural feature such as a frame or a keel. For models without a structural feature, the envelope relies solely on the lift gas to maintain its shape.

2.1.2 Lift Gas

Helium is by far the most commonly used lift gas in tethered aerostat systems. However, some vendors will make envelopes capable of using hydrogen gas. Hydrogen’s advantages include its greater availability, lower cost, and ability to provide more lift. However, hydrogen is highly flammable and has been banned in some countries for use in commercial aerostat applications. Helium is non-combustible and therefore much safer to use than hydrogen.

2.1.3 Transportation Method

Transportation is required to carry the tethered aerostat system to the deployment site. Trucks are used most often to haul system components, mooring stations, and launchers. The size of the system will determine transportation requirements (e.g., pickup truck, flatbed, or horse trailer).

Tethered aerostats can also be transported by sea or air depending on the system. The considerations influencing the selection of a transportation method for a particular system are discussed in Section 4.3.2.

2.1.4 Mooring Stations and Launchers

The operational stages of a tethered aerostat are inflation, mooring, launch, flight, deflation, and recovery. Between the inflation and launch stages, the envelope is held in place by equipment known as a mooring station or a launcher.

Although these terms are often used interchangeably, a mooring station generally has one or more masts that can hold the inflated envelope in place before and after flight. Additionally, on some mooring stations, either the platform or mast must be able to rotate so that the inflated envelope can move with the changing direction of the prevailing wind to avoid damage. This is primarily related to large aerostat envelopes. Launchers perform the same function as mooring stations but are generally associated with smaller aerostat systems that can be moored by the tether lines.

Some mooring stations are pre-fabricated and designed to function as a component of one or more tethered aerostat systems. Mooring stations can also be custom-built for use with certain sizes or types of aerostats or in place of a pre-fabricated mooring station. In addition, some mooring stations are designed to function as launchers.

What constitutes a mooring station and launcher can vary significantly among different tethered aerostat systems. Smaller aerostats can use relatively simple, lightweight equipment for mooring and launching the envelope, whereas larger models will require more elaborate components. Some examples of mooring stations and launchers are shown in Figure 2-2 and Figure 2-3.

Figure 2-2. Smaller Tethered Aerostat Mooring Stations and Launchers

Figure 2-3. Larger Tethered Aerostat Mooring Stations and Launchers

Some tethered aerostats can be deployed at sea from ships and barges and may require mooring stations and launchers designed for maritime applications. In other instances, a fully functional launcher may not be required, and the system can be operated with one or more winches.

2.1.5 Winches

Tethered aerostat system winches are spool-like devices used for letting out and pulling in the tethers during launch and recovery. Additionally, winches are used to adjust the tension of the tethers while the envelope is aloft. The spool around which the tethers coil is often referred to as the winch drum. Winch design can vary significantly between systems. Smaller aerostats can be operated manually with fishing or wooden hand reels; larger aerostats will require powered winches, which include electric, internal combustion, and hydraulic models. Powered winches provide varying levels of torque and may include features such as:

- Variable speed and braking (i.e., stopping) controls;
- Line leveling for safeguarding the tethers; and
- Slip rings for transmitting power and signal to electrical and fiber optic tethers.

Some powered winches also offer programmable controllers and wireless operation capabilities as well as options for operating the winch in case the controller fails. Depending on the tethered aerostat system, the winches can be standalone units; mounted to a truck bed, flat bed, or trailer hitch; or affixed to a mooring station and/or launcher.

2.1.6 Tethers

The tethers of a tethered aerostat system serve the following functions:

- Mooring the aerostat to ground equipment and maintaining its stability once aloft;
- Transmitting power to the aerostat and its payload equipment (e.g., cameras, sensors, communication repeaters); and
- Transmitting data and communications from the payload equipment to a ground control station or to mobile devices.

The tether lines coil around the winch drums on one end and are attached to the envelope on the other. Through the use of the winches, the tethers are let out during the launch stage, adjusted during flight, and retracted during the recovery stage.

Mooring tethers are typically made from synthetic fiber (e.g., nylon, Dyneema®, Spectra®) and vary in strength, weight, and diameter in accordance with the material used and the number of strands. To transmit electricity, a power line made of a conductive material, such as copper, is added alongside a synthetic fiber tether, known as the strength member. To transmit data and communications, one or more fiber optic strands can be similarly added. Power can be supplied to the tether from various means that include generators, alternators, or batteries; the amount of electricity needed to operate a system will depend on the power requirements of both the payload equipment and the aerostat system.

Tether components are encased in either a cloth sleeve or a plastic coating to protect and hold them together. A shielding to protect against damage from lightning strikes can also be added.

Smaller tethered aerostat systems may require only a single tether, which can include power and fiber optic capabilities, while larger systems may require several mooring tethers in addition to a tether with power and fiber optic capabilities. In situations where less power is required, onboard batteries can power the payload equipment and non-powered synthetic tethers are used to operate the aerostat.

2.1.7 Payload

The payload is the amount of weight an aerostat can carry aloft. The term is also used to refer to the equipment carried by the aerostat. The payload of a tethered aerostat system, as shown in Figure 2-4, can either be attached to a mounting device on the bottom of the envelope or placed close to where a main tether connects to payload support lines attached to the envelope.

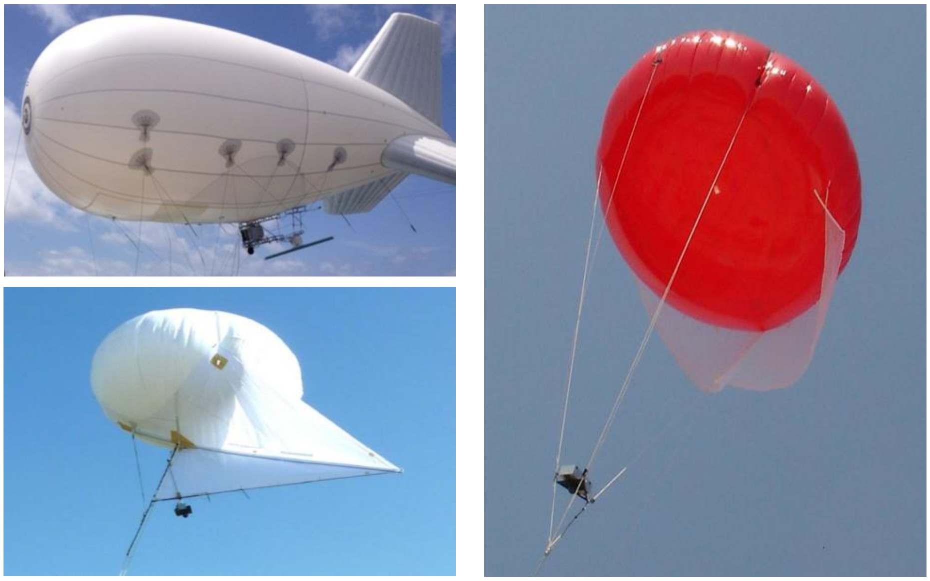

Figure 2-4. Tethered Aerostat Payload Configurations

Tethered aerostat systems can support a variety of equipment including stabilized high-resolution video cameras, EO/IR sensors, communication repeaters, acoustic detectors, and radar. In some cases, payload equipment is modular and can be substituted or upgraded to meet changing mission requirements.

2.1.8 Ground Control Station

Ground control stations can be used with tethered aerostat systems as a base of operations for a variety of purposes including:

- Housing computer workstations used by operators for controlling and monitoring the aerostat and its payload equipment;
- Housing servers used for storing transmissions received from the aerostat such as data and video; and
- Operating the COP software needed for some missions.

Any type of shelter can serve as a ground control station including a vehicle, tent, building, or a shipping container. In some cases, the vehicle used to transport the aerostat equipment can also serve as its ground control station.

3. REGULATIONS

The regulations associated with operating a tethered aerostat system are described below.

3.1 Federal Aviation Administration

The Federal Aviation Administration (FAA) requires that all tethered aerostats have an automatic device that will rapidly deflate the envelope in case it breaks loose from its tethers. Automated deflation devices include:

- Units that are activated by a global positioning system (GPS) sensor once the envelope reaches a specified distance from a particular location; and
- Units that are activated by a barometric pressure sensor once it registers a specified pressure level, indicating that the aerostat has exceeded a predetermined altitude.

Additionally, aerostat operators can use a radio-controlled device to deflate the envelope manually.

The FAA also requires the aerostat and its tethers to be illuminated if the system is operated between sunset and sunrise. A complete list of regulations concerning the operation of tethered aerostats can be found in the Code of Federal Regulations, Title 14, Part 101. This information can be accessed on the Electronic Code of Federal Regulations website (http://www.ecfr.gov).

3.2 Federal Communications Commission

Agencies intending to operate communications equipment on tethered aerostat systems may be subject to Federal Communications Commission (FCC) regulations. Depending on the equipment and how it will be used, different FCC rules will apply and proper licensing must be obtained. Product vendors should be able to help customers coordinate with the FCC in meeting relevant requirements.

3.3 Department of Transportation

Department of Transportation (DOT) regulations may apply to trailers used to haul tethered aerostat equipment, shipping containers, or to mobile mooring and launching equipment.

Agencies should ensure that all of the transportation equipment used complies with applicable DOT regulations.

4. CONSIDERATIONS

The selection of a tethered aerostat system will depend on a variety of considerations beginning with an agency's mission requirements. Once these requirements are defined, the agency can consider other factors associated with the geographical environment and weather conditions of the deployment site, component functionality and integration, system operations, costs, training, and system maintenance.

4.1 Agency Mission Requirements

Agency mission requirements should guide the selection of components for a tethered aerostat system. At a strategic level, these requirements can be divided into two operational categories: persistent and tactical. Persistent operations (e.g., single location border surveillance) are long-term and require the ongoing presence of a tethered aerostat system. Tactical operations (e.g., a search-and-rescue mission) are shorter in duration and require a system that can be easily transported, set up, and taken down.

4.2 Geographical Environment and Weather Conditions

The geographical environment and weather conditions of the deployment site should also be considered when selecting system components. Depending on the mission, tethered aerostats may need to be deployed in land environments such as the desert, plains, mountains, and urban areas. Tethered aerostat systems may also be deployed at sea, for example, in order to enhance network communications capabilities. In terms of weather conditions, the key factors that should be considered include temperature and wind speed.

It is important to understand that a decrease in air density will decrease the lift capacity of an aerostat. Consequently, because air density decreases at higher altitudes and is reduced by higher temperatures, an aerostat can support less payload at higher ground elevations and in warmer weather conditions.

4.3 Component Functionality and Integration

The following considerations relate to the functionality and integration of components such as the aerostat envelope, transportation method, mooring station, tethers, and payload equipment.

4.3.1 Aerostat Envelope

Some of the key considerations concerning the aerostat envelope include:

- **Transportation Dimensions:** The dimensions of the envelope, usually prior to its inflation, when being transported to the deployment site.
- **Inflated Dimensions:** The dimensions of the envelope after inflation.
- **Volume:** The amount of the space within the inflated envelope occupied by the lift gas, usually measured in cubic feet.

- **Launch Wind Speed:** The maximum wind speed, measured in knots, above which the aerostat cannot be launched.
- **Operational Wind Speed Range:** The range of wind speed in which an aerostat is designed to operate.
- **Survivable Wind Speed:** The maximum wind speed an aerostat can withstand before sustaining damage.
- **Maximum Operational Altitude:** The maximum altitude at which an aerostat is designed to operate.
- **Maximum Operational Temperature:** The maximum temperature at which an aerostat is designed to operate.
- **Usable (or Net) Payload Capacity:** The payload an aerostat can support. This does not include the weight of the tethers.
- **Mission Duration Before Lift Gas Refill:** The amount of time an aerostat can remain aloft before the envelope must be refilled with the lift gas.

4.3.2 Transportation

The transportation method used for a particular system will depend on several factors including the following:

- The transportation dimensions of the envelope (i.e., before it is inflated);
- The size and weight of the apparatuses needed to moor, launch, and control the system;
- The type of trailer (e.g., flatbed, utility, and horse trailers) needed to transport system components;
- The number and types of components needed for the system to meet its operational requirements; and
- The geographical and environmental conditions of the deployment site.

4.3.3 Mooring Stations and Launchers

The type of mooring station or launcher available for use with a system will depend on factors such as the size of the aerostat envelope, the types and number of tethers, and the deployment site. In addition, agencies may have the option in some instances to choose between a pre-fabricated or customized mooring station or launcher.

4.3.4 Winches

The winch or winches used with a system will depend primarily on the aerostat envelope and the type and number of tethers required for deployment. In general, winches are purchased through a third-party manufacturer and should be selected based on their ability to function with the tethers.

4.3.5 Tethers

The weight and dimensions of the tethers are also important considerations. Adding a power line, a lightning shield, or an extra fiber optic strand for redundancy in case one breaks will all increase the weight of the tether, reducing the payload equipment weight an aerostat can support. Because of its potential to affect the flight dynamic of an aerostat, a tether line should also be properly sized in length and diameter.

Moreover, an agency must determine the power, data, and communication requirements of the system. In cases of higher power requirements, electricity should be supplied to the aerostat through a tether, whereas in cases of lower power requirements, adequate electricity may be supplied via onboard batteries. For data and communication channels, an agency may have a choice between a wired (i.e., fiber optics included in the main tether line) or wireless (e.g., 4G) solution. In some instances, a combination of wired and wireless capabilities may best serve the agency's mission requirements.

4.3.6 Payload and System Integration

The selection of payload equipment should be based on mission requirements. Moreover, the weight of the selected payload equipment will be a primary consideration in choosing an aerostat envelope, which will then help determine the required number and types of tethers, winches, and other system components including, if necessary, a ground control station. For deployment, the diverse components of a tethered aerostat system must be properly integrated and configured and be able to meet both mission and environmental demands.

4.4 System Operations

Considerations associated with system operations are also important. The time required to setup and take down, or recover, a system will impact its suitability for certain types of operations. Speedy setup and recovery times are especially important for tactical operations in which the system needs to be moved quickly and frequently to different deployment sites. Setup and recovery times may be less important for persistent operations in which the system is not expected to be relocated for extended periods.

For many systems, the number of personnel required for set up is greater than the number of personnel required for operation. These personnel can be agency staff members or for a fee some vendors will provide field service representatives to assist with deploying the system. Of course, the number of personnel needed for deployment increases with the size and complexity of the system and will have an impact on the agency's overall operating cost.

4.5 Costs

Tethered aerostat systems vary widely in cost. Smaller systems with fewer components can cost a few thousand dollars while larger systems with many components, can cost several million dollars. Depending on the mission requirements and payload equipment, agencies may need to purchase additional computer hardware and software for the system to be fully functional. These components are generally operated from a ground control station and may include the computer workstations and software used for operating the aerostat and payload equipment, servers for storing transmissions received from the aerostat such as data and video, and COP software. A cost associated with the vendor's shipping of the aerostat and its components may also apply.

As an option, agencies may lease rather than purchase a tethered aerostat system for short-term or intermittent use. This type of arrangement will eliminate not only the costs of owning a system, but also those associated with system training, maintenance, and storage. As a cost-saving measure, an agency may also include a requirement for the vendor to supply a system operator in the leasing agreement.

4.6 Training

Training is most often provided by vendors, who can instruct agency personnel to become trainers, thereby reducing future training expenditures. However, additional training on the operation of payload equipment and software may be required. To avoid liability issues, vendors may require agencies to complete a training and certification program before purchasing and operating some tethered aerostats, and the time and costs associated with training will depend on the complexity of the system.

4.7 System Maintenance

A tethered aerostat requires regular maintenance, which includes patching the envelope, re-ending (i.e., repairing) tethers, and oiling winches. Moreover, after repeated re-ending repairs, tethers eventually become too short for operation and will need to be replaced.

System components and parts often come with warranties that apply for a certain period of time following the purchase. Vendors may also provide a recommended maintenance schedule, a list of recommended spare parts, and envelope patch kits. Instructions on how to patch an envelope and re-end a tether may be part of the included training.

For an additional cost, vendors may offer service agreements relating to system maintenance as well as a full set of spare parts. For parts supplied by a third-party manufacturer, the vendor will pass on the manufacturer’s warranty to the purchasing agency.

Vendors may also provide post-sales support to an agency through telephone, e-mail, or field service representative support. A field service representative can assist with on-site system troubleshooting and repair and may work on a contract basis year-round with an agency.

5. APPLICATIONS

Tethered aerostats can be used in a variety of operational scenarios. Examples of applications of these systems by agency type are provided in Table 5-1.

Table 5-1. Tethered Aerostat System Applications

Emergency Management	Homeland Security	Law Enforcement
• Fire control • Man-made disaster relief • Natural disaster relief • Search and rescue	• Border security • Harbor and coastal monitoring • Critical infrastructure security (e.g., power plants) • Sensitive site surveillance	• Crowd management • Drug interdiction • Event surveillance • Traffic monitoring

6. TETHERED AEROSTAT SYSTEM VENDORS

Some vendors of tethered aerostat systems manufacture and/or own the design patents on one or more components (e.g., envelopes, tethers, and launchers) and will integrate them with other components purchased from third-party manufacturers. Other vendors will purchase all system components from third-party manufacturers and build an integrated system for their customers. Vendors of tethered aerostat systems and components include those listed in Table 6-1.

Table 6-1. Tethered Aerostat System Vendors

Vendor	Address/Phone Number	Website/E-mail Address
Aeros Aeronautical Systems Corporation	1734 Gage Road Montebello, CA 90640 (818) 344-3999	http://www.aeroscraft.com aeroscraft@aeroscraft.com
Allsopp Helikites Limited	South End Farm, Damerham, Fordingbridge, Hampshire SP6 3HW England, UK +44 (0) 1725-518750	http://www.allsopphelikites.com helikites@yahoo.com
Carolina Unmanned Vehicles, Inc.	4105 Graham-Newton Road Raleigh, NC 27606 (919) 851-9898	http://carolinaunmanned.com cuvinc@carolinaunmanned.com
Focus Consulting & Services, LLC (Distributor for RT LTA Systems Limited)	8960 Colesbury Place Fairfax, VA 22031 (703) 593-8725	http://www.rt.co.il info@rt.com
Near Space Systems, Inc.	2375 Telstar Drive, Suite 115 Colorado Springs, CO 80920 (719) 685-8108	http://www.globalnearspace.com
ILC Dover	1 Moonwalker Road Frederica, DE 19946 (800) 631-9567	http://www.ilcdover.com customer_service@ilcdover.com
Lighter Than Air Systems Corporation	11653 Central Parkway, #209 Jacksonville, FL 32224 (800) 973-9110	http://ltascorp.com
Lindstrand USA, Inc.	2202 Parker Avenue South Boston, VA 24592 (434) 572-3445	http://www.lindstrandusa.com sales@lindstrandusa.com
Raven Aerostar Aerostar International, Inc.	909 W. Algonquin Street Sioux Falls, SD 57104 (605) 331-3500	http://ravenaerostar.com http://ravenaerostar.com/contact
SkyDoc™ Systems, LLC	(503) 396-8417	http://www.skydocballoon.com charlie@skydocballon.com

Vendor	Address/Phone Number	Website/E-mail Address
SkySentry	11605 Meridian Market View Suite 124-333 Falcon, CO 80831 (719) 495-7856	http://www.skysentry.net info@skysentry.net
TCOM, L.P.	7115 Thomas Edison Drive Columbia, MD 21046 (410) 312-2400	http://www.tcomlp.com aerostat@tcomlp.com
Top I Vision, Ltd.	25 Hathiya Street Holon 58402 Israel +972-3-9335469	http://www.topivision.com info@topivision.com
Vigilance Systems	Lireweg 6 2153 PH Nieuw Vennep Netherlands +31-252-624-588	http://www.vigilance.nl info@vigilance.nl

7. CONCLUSION

Tethered aerostat systems can provide emergency responders with a cost-effective means of performing a variety of short- and long-term emergency management, homeland security, and law enforcement operations.

Although agencies will have many options when selecting components, mission requirements are a key consideration in determining the size and complexity of the system. Knowing these requirements will then give the agency a foundation for exploring other considerations associated with the deployment site, component functionality and integration, system operations, costs, training, and maintenance.

In addition, agencies may want to consider leasing instead of purchasing a tethered aerostat system. For help with these decisions, agencies can consult with both component vendors and system integrators, who can provide guidance by building a solution that best meets the requirements of an agency's mission.